APPENDIX A

Present Value (or worth): An economic concept that represents the translation of specified amounts of costs or benefits occurring in different time periods into a single amount at a single instant (usually the present). Two related considerations underlie the need for computing present values: (1) the fact that money has an intrinsic capacity to earn interest over time (known as the time value of money) due to its productiveness and scarcity, and (2) the need in an economic study for comparing or summing incremental outlays or savings of money in different time periods.(1)

Equivalent Uniform Annual Cost (or Benefit): A uniform annual cost (or benefit) that is the equivalent, spread over the entire period of analysis, of all incremental disbursements or costs incurred on (or benefits received from) a project. The present value of the uniform series of equivalent annual costs equals the present value of all project disbursements.(1)

Discount Rate (Interest rate, Time Value of Money): A percentage figure—usually expressed as an annual rate- representing the rate of interest money can be assumed to earn over the period of time under analysis. A governmental unit that decides to spend money improving a highway, for example, loses the opportunity to “invest” this money elsewhere. That rate at which money could be invested elsewhere is sometimes known as the “Opportunity Cost of Capital” and is the appropriate discount rate for use in economic studies. Discount factors derived as a function of the discount rate and time period relative to the present can be used to convert periodic benefits and costs for a project into present value or into equivalent uniform annual cost. However, calculating benefits in constant dollars and using market rates of interest is an error because the market rate of return includes an allowance for expected inflation. Hence, if future benefits and costs are calculated in constant dollars, only the real cost of capital should be represented in the discount rate used. The discount rate assumes annual end-of-year compounding, unless otherwise specified. The sum of $100 in cash today is equivalent, at a 10 percent discount rate, to $110 a year from now, $121 at the end of the second year, and $259.37 at the end of the tenth year. Correspondingly, a commitment to spend $259.37 in the tenth year discounted at 10 percent has a present value of $100.(1)

Residual or Salvage Value: The value of an investment or capital outlay remaining at the end of the study or analysis period.

The equation for determining the present worth or rehabilitation and maintenance costs for a given facility is as follows:

$$PW = C + Mi\left(\frac{1}{1+r}\right)^{ni} + \;.........\; Mj\left(\frac{1}{1+r}\right)^{ni} - S\left(\frac{1}{1+r}\right)^{N}$$

where:

PW = Present worth or present value of all costs
C = Present cost of initial rehabilitation activity

Mi = Cost of the ith maintenance & rehabilitation (M&R) alternative in terms of constant dollars
r = Discount rate
ni = Number of years from the present to the ith M & R activity
S = Salvage value at the end of the analysis period
N = Length of the analysis period in years

The term $\left(\frac{1}{1+r}\right)^{n}$ is commonly called the single payment present worth factor.

The present worth or present value of all costs over the analysis period can be stated in terms of EUAC by multiplying PW by the uniform series capital recovery factor:

$$
\begin{aligned}
EUAC &= PWX\ crf(r,N) \\
&= PWX\ \frac{r(1+r)^N}{(1+r)^N-1}
\end{aligned}
$$

where:

PW = Present Worth as before
crf (r, N) = The uniform series capital recovery factor for discount rate r and analysis period N

The major initial and recurring costs that should be considered in the economic evaluation of alternative techniques include the following:(2)

1. Agency Costs:
   a) Initial construction costs.
   b) Future construction or rehabilitation costs (overlays, seal coats, reconstruction, etc.)
   c) Maintenance costs, recurring throughout the design period.
   d) Salvage return or residual value at the end of the design period (which may be a “negative” cost).
   e) Engineering and administration costs.
   f) Traffic control costs if any are involved.
2. User Costs:
   a) Travel time.
   b) Vehicle operation.
   c) Accidents.
   d) Discomfort.
   e) Time delay and extra vehicle operating costs during resurfacing or major maintenance.

For a simplified analysis, the following costs are usually considered for life cycle analysis:

1. Initial capital costs of rehabilitation.
2. Future capital costs of reconstruction or rehabilitation.
3. Maintenance costs.
4. Salvage value.

However, certain user costs such as time delay costs during rehabilitation must be considered on certain facilities.[3] Factors that must be considered when determining these costs include:

1. Will the roadway be closed over a lengthy period of time?
2. Are alternate roadways available?
3. Can operations be moved to a different facility?
4. What are the costs of traffic delays associated with closing the facility?

For present worth calculation, a discount rate of four percent is suggested.[4] It is recommended that because the results of present worth analyses are sensitive to the discount rate, economic calculations at two or three discount rates of 4, 7, and 10 percent be made for a sensitivity analysis (3). Alternatives with large initial costs and low maintenance or user costs are favored by low rates of return. On the other hand, high discount rates favor strategies that combine low initial costs and higher maintenance and user costs.

The 4 percent discount rate must be used with constant dollar costs at the time the analysis is conducted and must remain fixed for the analysis period. For example, if an asphalt concrete pavement is to be constructed, the cost of asphalt concrete at the time of an overlay 20 years after construction should be the same as at the time of initial construction.

The following reasons against inclusion of inflation rates in economic studies have been advanced:[3]

1. Difficulties in predicting future inflation rates.
2. The acceptance of inflation as a norm may be counter to the government’s responsibility for price stabilization.
3. Federal programs, if justified in part by inflating benefits, may contribute to inflation.
4. Debtor’s gains through repaying outstanding debts with inflated dollars are offset by creditors’ losses.
5. Future dollars to pay for future expenses will likewise be inflated and therefore there is no net change.

Life Cycles

An important factor in identifying and performing economic analyses of alternatives in the design of new pavement construction and/or the repair and rehabilitation of existing pavement is the life cycle of the alternative under consideration. The life cycle is the period of time of actual use before replacement, reconstruction, or extensive rehabilitation is required. Obviously, there is a time variation of specific service lives between project sites for a given pavement alternative. Therefore, the life cycle is an overall average of service lives of the specific service lives for identical pavement alternatives experienced at various project sites. The designer may use the generally accepted life cycle for a particular alternative, such as 40 years with maintenance for new PCC pavement, or he/she may elect to use a different life cycle for the same alternative, such as 30 years with little or no maintenance. Table A-1[3] shows typical life cycles for new pavement construction and pavement overlays.

Table A-1. Estimated life cycles of new pavements and overlays.[3]

Pavement Type	Representative Ranges*
New PCC	15 - 25
PCC Overlay	7 - 14
New AC	12 - 20
AC Overlay	8 - 12

Note:
* Varies depending on location, traffic, thickness, existing pavement condition, etc.
PCC - Portland Cement Concrete, AC - Asphalt Concrete.

Table A-2. Maintenance activity life cycles.[4]

Maintenance Activity	Life Cycle (Years)
Crack Sealing (flexible)	4
Chip Seal (flexible)	5
Shallow Patch (flexible)	3
Deep Patch (flexible)	6
Slurry Seal (flexible)	6
Cold Milling (flexible)	10
Heater Planing (flexible)	6
Crack Sealing (rigid)	5
Joint Sealing (rigid)	7
Shallow Patch (rigid)	5
Deep Patch (rigid)	8
Slab Replacement (rigid)	19
Grinding (rigid)	11
Mud Jacking (rigid)	16

Pavement repair, maintenance, and rehabilitation life cycles were derived from responses to a questionnaire in 1985 from more than 40 Air Force bases.[3] Respective maintenance activity lives were averaged for all locations in the survey and rounded to the nearest year to arrive at the life cycle for the particular alternative, and are listed in table A-2.[4]

Analysis Life

In performing economic studies of projects under consideration an economic life, service life and analysis life must be established. The service life is the time period of actual use. The economic life is the time period over which a project is economically profitable, or until the service by the project can be provided by another facility at lower costs. The economic life may be less than the service life. Lack of capital may extend a project service life beyond the end of its economic life. Economic life usually ends when the physical deterioration of a pavement proceeds to the point where reduced service and increased maintenance costs justify replacement with an alternative having expected lower life-cycle costs.

Analysis life may not be the same as the service life or economic life of a project, but it is a realistic estimate for use in an economic analysis. The analysis life period selected should be long enough to include the time between major rehabilitation actions for the various alternatives under study, but not so long as to make the analysis uncertain. Suggested values to use for analysis life are shown in table A-3.[3]

Salvage Value

The salvage value of a pavement structure is the residual value at the end of the analysis period. If at the end of this analysis period, it is expected that the facility will be abandoned, the salvage value is any value that the materials may have if removed and reused. In general, it is practical to assume that the salvage value is zero unless specific data are available to calculate otherwise. However, the facility may possess useful life after the analysis period, and if so, the salvage value should be included in the life-cycle cost analysis. The residual value of the last rehabilitation action based on its anticipated remaining life appears to be the best method for determining salvage value. A simplified, but adequate, method for estimating the salvage value can be calculated with the following equation:

$$SV = 1 - \left(\frac{L_A}{L_E} \right) C$$

where:

SV = salvage value (or residual value) of rehabilitation alternative
L_A = analysis life of rehabilitation alternative in years, i.e., difference between the year of construction and the year of termination of the life cycle analysis
L_E = expected life of the rehabilitation alternative
C = cost of the rehabilitation alternative

Use of this simplified approach in estimating salvage value is justified by the fact that there are several uncertainties associated with the service lives and costs for the different pavement component layers, and the relatively small impact that salvage value actually has on life cycle comparisons.

Table A-3. Recommended analysis life for comparing alternatives.[3]

Activity	Pavement Surface Type	Recommended Analysis Life, Years
New construction, reconstruction or thick overlays	PCC and AC PCC Only AC Only	45 45 30
Rehabilitation	PCC Only AC Only	20 20
Maintenance	PCC Only AC Only	20 10

Note:
PCC - portland cement concrete.
AC - asphalt concrete.

The following is an example situation[3] in which the above equation can be used to calculate the estimated salvage value: If an analysis period of 20 years is used on a project where a rehabilitation alternative has a life cycle of nine years, the residual or salvage value of the second rehabilitation action is equal to the straight-line depreciated value of the alternative at the end of the analysis period as follows:

$$SV = \left(1 - \frac{2}{9}\right) \$3.12 \ (\$2.50) = \$2.43 \ (\$1.94)$$

(Assuming cost of the rehabilitation alternative is 3.12 per square meter, $2.50 per square yard). A more detailed discussion of salvage value and other terms used in this section is contained in Reference 2.

Price Data

Price data are needed for construction, rehabilitation and maintenance operations. Sources of these data include:

1. Local records.
2. State records.
3. Experience.
4. Bid summaries.

Price data for recycling and other rehabilitation operations are discussed further in chapter 6: Summary and Cost Data.

Example of Life Cycle Cost Analysis

A simplified example of a life cycle cost analysis is shown in tables A-4 to A-7.[3] Table A-4 shows cost data for rehabilitation alternatives considered for a project in the southwestern United States. A typical calculation sheet for determining present worth and equal uniform annual cost is

Table A-4. Representative costs of rehabilitation alternatives.[3]

Rehabilitation Alternative	Costs \$/m² (\$/yd²)
Asphalt cement chip seal	1.08 (0.86)
Asphalt-rubber chip seal or interlayer	1.56 (1.25)
Fabric interlayer	1.50 (1.20)
Heater scarification	1.12 (0.90)
Asphalt concrete - 25 mm (one in)	2.06 (1.65)
Asphalt rubber interlayer with 36 mm (1.4 in) asphalt concrete	4.66 (3.73)
Fabric interlayer with 38 mm (1.5 in) asphalt concrete	4.60 (3.68)
Heater scarification with 38 mm (1.5 in) asphalt concrete	2.79 (2.23)
Cold recycle 152 mm + 50 mm (6 in + 2 in) asphalt concrete	8.25 (6.60)
Hot recycle 177.8 mm (7 in)	10.12 (8.10)

shown in table A-5. Table A-6 shows costs associated with seven rehabilitation alternatives. A summary of first costs and life cycle costs is shown in table A-7.

Table A-5. Calculation form for present worth life cycle costing.[3]

Year	Cost, Dollars per sq m (sq yd)	Present Worth Factor, 4%	Present Worth, Dollars
Initial Cost	1.56 (1.25) A-R Chip Seal	1.0000	1.56 (1.25)
1		0.9615	
2		0.9246	
3	0.31 (0.25) maintenance	0.8890	0.27 (0.22)
4	6.19 (4.9) 76 mm AC (3") AC	0.8548	5.29 (4.23)
5		0.8219	
6		0.7903	
7		0.7599	
8		0.7307	
9		0.7026	
10	0.12 (0.10) maintenance	0.6756	0.08 (0.07)
11	0.12 (0.10) maintenance	0.6496	0.08 (0.06)
12	0.12 (0.10) maintenance	0.6246	0.07 (0.06)
13	0.19 (0.15) maintenance	0.6006	0.11 (0.09)
14	0.31 (0.25) maintenance	0.5775	0.18 (0.14)
15	3.12 (2.50) 38 mm AC (1-1/2") AC	0.5553	1.73 (1.39)
16		0.5339	
17		0.5134	
18		0.4936	
19	0.12 (0.10) maintenance	0.4746	0.06 (0.05)
20	0.19 (0.15) maintenance	0.4564	0.09 (0.07)
Salvage Value	0.89 (0.71)	0.4564	-0.41 (-0.32)
Total	11.49 (9.19)	Total	9.14 (7.31)

Notes:

Uniform Annual Cost = Present Worth x Capital Recovery Factor
= 9.14 x (7.31) x 0.07358
= 0.672 (0.538)

Table A-6. Life cycle costs associated with rehabilitation alternatives dollars per square meter (dollars per square yard).[3]

Year	Rehabilitation Alternatives						
	1 AR Chip Seal	2 76 mm (3" AC)	3 HS + 50 mm (2" AC)	4 A-R + 50 mm (2" AC)	5 Fabric: + 50 mm (2" AC)	6 Cold Recycle	7 Hot Recycle
Initial	1.56 (1.25)	6.19 (4.95)	5.25 (4.20)	3.64 (4.55)	5.62 (4.50)	6.60	8.10
1							
2		0.12 (0.10)					
3	0.31 (0.25)	0.19 (0.15)					
4	6.19 (4.95)	0.25 (0.20)					
5		0.25 (0.20)	0.12 (0.10)		0.12 (0.10)		
6		0.31 (0.25)	0.12 (0.10)		0.12 (0.10)		
7		3.12 (2.50)	0.12 (0.10)		0.12 (0.10)		
8			0.19 (0.15)	0.12 (0.10)	0.19 (0.15)		
9		0.12 (0.10)	0.31 (0.25)	0.12 (0.10)	0.31 (0.25)		
10	0.12 (0.10)	0.19 (0.15)	3.12 (2.50)	0.12 (0.10)	3.12 (2.50)	0.05	
11	0.12 (0.10)	0.25 (0.20)		0.19 (0.15)			
12	0.12 (0.10)	0.25(0.20)		0.31 (0.25)		0.05	0.05
13	0.19 (0.15)	0.31 (0.25)		3.12 (2.50)			
14	0.31 (0.25)	3.12 (2.50)	0.12 (0.10)		0.12 (0.10)	0.10	0.05
15	3.12 (2.50)		0.19 (0.15)		0.19 (0.15)	0.15	
16		0.12 (0.10)	0.31 (0.25)		0.31 (0.25)	0.25	0.10
17		0.19 (0.15)	3.12 (2.50)	0.12 (0.10)	2.50	2.50	
18		0.25 (0.20)		0.19 (0.15)			0.10
19	0.12 (0.10)	0.25 (0.20)		0.31 (0.25)			0.20
20	0.19 (0.15)	0.31 (0.25)		3.12 (2.50)			0.25
Salvage Value	0.89 (0.71)	0.45 (0.36)	1.79 (1.43)	3.12 (2.50)	1.43	1.43	0

Notes:

A-R - Asphalt Rubber
H-S - Heater Scarification
AC - Asphalt Concrete

Table A-7. Project summary sheet.[3]

Description of Project:
Location: Southwestern United States
Type of Facility: Runway, length 975.36 m (3,200 ft) - width 22.8 m (75 ft)
Critical Aircraft: 10.89 Mg (24,000 lbs.) gross weight
Annual Departures: 3,000

Existing Pavement:

Type of Material	Thickness mm (in)	Condition	Equivalency Factor	Equivalent Thickness mm (in)
AC Surface	100 (4)	Fair	1.2	122 (4.8)
Untreated Base	254 (10)	Good	1.0	254 (10.0)
Subgrade				

Total: 376 (14.8)

Condition of Pavement:
Condition Survey: Alligator cracking, moderate 20 percent of area; transverse cracking, moderate, 1-4 per station; longitudinal cracks, moderate, 45.72 m (150 ft) per station.
Skid Resistance: Good
Required Thickness of New Pavement: 457 mm (18") min. 50 mm (2") AC, 127 mm (5") base
Equivalent Thickness of Old Pavement: 376 mm (14.8")
Required Overlay Thickness: 76 mm (3") AC

Rehabilitation Alternatives:

	First Cost $/m² ($/yd²)	Life Cycle PW, $/m² ($/yd²)	Time for Rehab.	Chance for Success
1. Asphalt-rubber chip seal to delay overlay	1.56 (1.25)	9.14 (7.31)	2 days	90
2. 75 mm (3 in) AC overlay	6.19 (4.95)	12.35 (9.88)	5 days	95
3. Heater scarification + 50 mm (2 in)	5.25 (4.20)	9.15 (7.32)	4 days	97
4. Asphalt-rubber interlayer + 50 mm (2 in) overlay	5.69 (4.55)	8.45 (6.76)	4 days	97
5. Fabric interlayer + 50 mm (2 in) overlay	5.62 (4.50)	9.52 (7.62)	4 days	97
6. Cold recycle with asphalt emulsion 152 + 50 mmAC (6" + 2"AC)	8.15 (6.60)	9.45 (7.56)	6 days	97
7. Hot recycle with AC 178 mm (7")	10.16 (8.10)	10.57 (8.46)	6 days	99

REFERENCES

1. J.A. Epps, D.N. Little, R.J. Holmgreen, and R.L. Terrel. *Guidelines For Recycling Pavement Materials,* NCHRP Report 224, TRB, National Research Council, Washington, DC, September, 1980.

2. American Association of State Highway and Transportation Officials (AASHTO). *AASHTO Guide for Design and Pavement Structures*, Washington, DC, 1986.

3. *Pavement Recycling Guidelines for Local Governments - Reference Manual*, Report No. FHWA-TS-87-230, FHA, U.S. Department of Transportation, Washington, DC, 1987.

4. Asphalt Recycling and Reclaiming Association. *An Overview of Recycling and Reclamation Methods for Asphalt Pavement Rehabilitation*, 1992.

APPENDIX B

NH-285-2 (17) 78
May 6, 1996

NEW MEXICO STATE HIGHWAY AND TRANSPORTATION DEPARTMENT
SPECIAL PROVISIONS
FOR
IN-SITU COLD RECYCLING WITH HOT HYDRATED LIME SLURRY
SECTION 305-A

All provisions of the New Mexico State Highway and Transportation Department's Standard Specifications for Highway and Bridge Construction shall apply in addition to the following:

305.1. DESCRIPTION

305.11. This work shall consist of pulverizing the existing surfacing to the specified width and depth, mixing an emulsified binder agent, hot hydrated lime slurry, and water if required, with the pulverized surfacing, spreading and compacting said mixture to the specified width and thickness, and sealing of the compacted surface if required. All work shall be as shown on the plans and as provided herein unless otherwise directed by the Project Manager.

305.2. MATERIALS

305.21. The emulsified binder agent shall be Polymerized High Float Emulsion of the type shown on the plans with the option to change one grade up or down at a change in unit price based on a difference in invoice prices for the different grades of emulsion. Changes in grade of binder agent shall be made only with the concurrence of the Project Manager. The Polymerized High Float Emulsion shall meet the requirements of Section 402 - Bituminous Materials, Hydrated Lime, & Liquid Anti-Stripping Agents.

305.22. The cold recycled material shall meet the following gradation requirements:

Table 1. Cold recycled pavement gradation requirements.

Sieve Size	Percent Passing
1¼"	100
1"	90-100

305.23. The sealing emulsion shall be diluted with High Float Emulsion, CSS-1h or other approved equal.

305.24. The lime used for the production of the hot hydrated lime slurry shall be a high calcium pebble quicklime meeting the requirements of ASTM C 977.

305.25. The water used for the production of hot hydrated lime slurry shall be clear and free of deleterious amounts of acid, oil, alkali, organic matter, salt, sugar, or other detrimental material. Water meeting the requirements of Subsection 510.25 Water, is acceptable.

305.26. The hot hydrated lime slurry shall have a minimum dry solids content of 35 percent by weight and shall consist of a uniform, pumpable suspension of solids in water.

305.3. CONSTRUCTION REQUIREMENTS

305.31. General. The existing surfacing shall be cold recycled in a manner that does not disturb the underlying material in the existing roadway.

Prior to initiating recycling operations or other inherent work, the Contractor shall clear, grub, and remove all vegetation and debris within the width of pavement to be recycled. Disposal of said vegetation and debris shall be as directed by the Project Manager.

The Contractor may add water to the pulverized material for the purpose of cooling the cutting teeth on the mill or pulverizing equipment or to facilitate uniform mixing with the emulsified binder agent. Water may be added prior to or concurrently with the emulsified binder agent. A means shall be provided for accurately metering and registering the rate of flow of water into the pulverized material.

When the typical section that is to be recycled is situated on a super elevated or sloped section, the initial pass of the milling equipment shall begin at the lowest portion of the section and proceed in succession towards the higher end of the slope.

Fillets of fine, pulverized material which form adjacent to a vertical face shall be removed prior to spreading the recycled mix, except that such fillets adjacent to existing pavement which will be removed by overlapping during a subsequent milling operation need not be removed.

If segregation occurs either in the windrow or behind the paver, the Project Manager may require the Contractor to make changes in the equipment or operations. These changes may include, but shall not be limited to, the following:

1. Reducing the forward speed of the milling operation.
2. Increasing the amount of material going through the crusher.
3. Adjusting the crusher to produce more fines.
4. Adjusting the height of free fall of material from the mixing unit.
5. Adjusting the amount of water in the mixture.

The Contractor may be required to make other changes in his equipment or operations, as necessary to obtain a satisfactory end-product.

When a paving fabric is encountered during the cold recycled in-situ operation, the Contractor shall make the necessary adjustments in the equipment or operations so that at least 90 percent of the shredded fabric in the recycled is five square inches or less in size. Additionally, no fabric piece shall have any dimension exceeding a length of four inches. These changes may include but not be limited to adjusting the milling rate, adding or removing screens, etc, in order to obtain a specification end product. The Contractor shall be required to waste material containing over-sized pieces of paving fabric as directed by the Project Manager. These changes will be made at not additional cost to the Department.

The recycled bituminous base shall be spread in one continuous pass, without segregation, to the typical section shown on the plans.

305.311. Surface Tolerance. The final surface of recycled bituminous base shall not deviate in excess of ½ inch from the testing edge with a 10-foot straightedge resting on any two points. all deviations from this tolerance shall be corrected at no additional cost to the Department.

305.32. Temperature & Weather Limitations. Recycling operations shall not be performed when the atmospheric temperature is below 60°F or when the chill factor is below 35°F or when the weather is foggy or rainy or when weather conditions are such that in the judgement of the Project Manager, proper mixing, spreading and compacting of the recycled material cannot be accomplished. The chill factor shall be as defined in Subsection 401.341 Temperature & Weather Limitations.

305.33. Binder Application. When commencing recycling operations, the emulsified binder agent shall be applied to the pulverized material at the rate determined by the Department based on samples obtained by the Contractor for the mix design. The exact application rate of the emulsified binder agent will be determined and varied by the Project Manager as required by existing pavement conditions. An allowable tolerance of plus or minus 0.2 percent of the initial design rate or of the rate determined by the Project Manager of application shall be maintained at all times.

305.34. Lime Slurry Addition. The quicklime shall be slaked with the required amount of water and uniformly incorporated into the pulverized surfacing at a rate that will result in 1.5% hydrated lime by dry weight of pulverized surfacing. The amount of lime slurry being added shall be controlled by the continuous weighing of the pulverized surfacing.

305.35. Density & Rolling Requirements. The Contractor shall establish a rolling pattern such that a minimum density of 96 percent of a laboratory briquette, prepared in accordance with Department molding and testing procedures, is obtained. The Project Manager may require a re-demonstration of rolling capabilities when a change in the recycled materials is observed, whenever a change in rolling equipment is made, or if densities are not being obtained with the rolling pattern being used.

Initial rolling shall normally be performed with a 30 ton pneumatic roller and continued until no displacement is discerned or until the pneumatic rollers have walked out. If necessary, in order to initially seat the mixture, one or two passes with a small pneumatic roller may be made prior to application of the 30 ton roller. Final rolling to eliminate pneumatic tire marks and achieve density shall be done by steel wheel roller(s), either in static or vibratory mode, as required, to achieve required density.

Rolling shall be performed in accordance with Subsection 401.35 Compaction.

Rollers shall not be started or stopped on uncompacted recycled material. Rolling shall be established so that starting and stopping will be on previously compacted recycled material or on existing PMBP.

Rolling which results in cracking, movement, or other types of pavement distress shall be discontinued until such time as the problem can be resolved. Discontinuation and commencement of rolling operations shall be at the sole discretion of the Project Manager.

305.36. Finishing Operations. After the recycled material has been spread and compacted, vehicles, including Contractor's equipment, shall not be permitted on the completed recycled bituminous base for at least two hours. The area may then be opened to all traffic and shall be allowed to cure such that the free moisture in the recycled material is reduced to one percent or less above the natural moisture of the material by total weight of mix, before placing the surfacing.

The surface of the recycled pavement shall be maintained in a condition suitable for the safe accommodation of traffic. All loose aggregate that develops on the surface of the recycled pavement shall be removed by power brooming. After the free moisture content of the recycled material is one percent or less above the natural moisture of the material, the Project Manager may require that the surface be sealed with emulsion at an approximate rate of 0.05 to 0.10 gallon per square yard in order to control surface raveling.

All unacceptable recycled bituminous base shall be repaired by the Contractor, as directed by the Project Manager prior to placing a subsequent surfacing course. Said repair(s) shall be made at no additional cost to the Department.

305.37. Equipment.

305.371. Cold In-Situ Machinery. The Contractor shall furnish a self-propelled machine capable of pulverizing in-situ bituminous materials to the depth shown on the plans in one pass. The machine shall have a minimum rotor cutting width of 12 feet, standard automatic depth controls and shall maintain a constant cutting depth. The machine shall also incorporate screening and crushing capabilities to reduce or remove oversize particles prior to mixing with emulsion. Oversize particles shall be reduced to size by crushing, however, the Contractor may, with concurrence of the Project Manager, waste up to a maximum of two percent oversize material prior to adding emulsion. This waste shall generally be limited to that material which is flattened out rather than broken down by the crusher.

The emulsified agent shall be applied through a mixing machine capable of mixing the pulverized material and the emulsified binder agent to a homogeneous mixture and placing the mixture in a windrow. The method of depositing the mixed material in a windrow shall be such that segregation does not occur.

A positive displacement pump, capable of accurately metering the required quantity of emulsified binder agent, into the pulverized material, shall be used. The pump shall be equipped with a positive interlock system which will permit addition of the emulsified binder agent only when the pulverized material is present in the mixing chamber and will automatically shut off when the material is not in the mixing chamber.

Each mixing machine shall be equipped with a meter capable of registering the rate of flow and total delivery of the emulsified binder agent introduced into the mixture. The meter shall be calibrated by the Contractor, in the presence of the Project Manager, before commencing recycling operations. Subsequent checks or calibrations of the meter shall be as directed by the Project Manager.

305.372. Lime Slurry Equipment. The lime slurry shall be produced at the job site using a batch type process. The equipment shall accurately proportion the quicklime and water; adequately mix the two to obtain proper slaking; and maintain a uniform, homogeneous slurry.

Transports used to convey the slurry to the roadway shall employ sufficient agitation to prevent settlement and maintain a uniform homogeneous mixture.

The lime slurry shall be added to the pulverized surfacing by a spray bar located at the cutting head on the milling machine. A metering device shall be used and it shall accurately measure the amount of slurry delivered to within plus or minus 10 percent by weight.

305.373. Pavers. Placing of the recycled bituminous base course shall be accomplished with a self-propelled bituminous paver meeting the requirement of Subsection 401.323 Pavers, except that heating of the screed will not be permitted. This equipment shall be capable of spreading the recycled bituminous base in one continuous pass, without segregation, to the typical section shown on the plans.

When a pick-up machine is used to feed the windrow into the paver hopper, the pick-up machine shall be capable of picking up the entire windrow down to the underlying materials.

305.374. Rollers. Rollers shall meet the requirements of Subsection 401.324 Compaction Equipment. The number, weight, and type of rollers shall be sufficient to obtain the required compaction while the mixture is in a workable condition except that one pneumatic roller shall be 30 ton minimum weight. All rollers shall be equipped with pads and a water system which prevents sticking of the recycled mixture to the roller wheels.

305.375. Brooms. The Contractor shall have on hand at all times a rotary power broom maintained in good working order and of a design suitable for removing aggregate that becomes dislodged from the surface of the recycled surface.

305.4. METHOD OF MEASUREMENT

305.41. In-situ cold recycling of existing surfacing will be measured by the square yard.

Polymer modified high float emulsion will be measured by the ton.

Sealing emulsion will be measured by the ton.

Quicklime will be measured by the ton.

305.5. BASIS OF PAYMENT

305.51. In-situ cold recycling of existing surfacing will be paid for at the contract unit price per square yard.

Polymer modified high float emulsion will be paid for at the contract unit price per ton.

Sealing emulsion will be paid for at the contract unit price per ton.

Quicklime will be paid for at the contract unit price per ton. This price will be full compensation for the quicklime, and production of the hot lime slurry including all necessary equipment, labor, and water.

Payment will be made under:

Pay Item	**Pay Unit**
In-Situ Cold Recycling of Existing Surfacing	Square Yard
Polymer Modified High Float Emulsion (Type)	Ton
Sealing Emulsion	Ton
Quicklime	Ton

APPENDIX C

MILL AND RELAY ASPHALTIC PAVEMENT. ITEM 90358.

A. Description. This work shall consist of constructing base course utilizing in-place milling and relaying of the existing asphaltic surface over the roadbed as shown on the plans and as hereinafter provided.

B. Construction Methods. The existing asphaltic surface shall be milled to the depth shown on the plans and to a maximum size of 37.5 mm. The milling machine shall be equipped with electronic devices which will provide accurate depth, grade and slope control.

Immediately after milling, the material shall be placed as shown on the plans. The laydown shall be accomplished using a paver or a grader or a combination of a paver and grader.

The relaid material shall be immediately compacted in the following sequence: first with either a rubber-tired roller or vibratory pads foot roller, and second with a vibratory steel roller. Water shall be added prior to and during compaction as required. Each layer shall be compacted to the extent required for Standard Compaction in Section 304.5 of the Standard Specifications. The compaction equipment shall be as follows:

> For a compacted depth of milled material, up to 150 mm, compaction equipment shall be in accordance with Section 304.4.4 of the Standard Specifications.
>
> For a compacted depth of milled material, greater than 150 mm and up to 200 mm, a minimum 22.68 megagram rubber-tired roller with 620 kPa tire pressure or 11335 kg pads foot vibratory roller, and a minimum 7.25 megagram vibratory steel roller shall be used.
>
> For compacted depths greater than 200 mm, split lift compaction according to the above described methods will be required.

At the completion of each working day, the ends of the mill and relay asphaltic pavement shall be as adjacent as practical for both traffic lanes.

C. Method of Measurement. Mill and Relay Asphaltic Pavement will be measured by the square meter of relaid material according to the finished typical section width and details shown on the plans.

D. Basis of Payment. Mill and Relay Asphaltic Pavement, as measured above, will be paid at the contract unit price per square meter, which price shall be full compensation for milling, windrowing, relaying, adding water, compaction, removing and disposing of excess material, and all labor, tools, equipment, and incidentals necessary to complete the work in accordance with the contract.
(022096)

PULVERIZE AND RELAY EXISTING BASE AND SURFACE. ITEM 90357

A. Description. This work shall consist of constructing base course utilizing in-place pulverizing and relaying of the existing asphaltic surface and base course over the roadbed as shown on the plans and as hereinafter provided.

B. Construction Methods. The existing asphaltic surface shall be pulverized full depth and to a minimum of 97 percent passing a 50 mm screen. The existing crushed aggregate base course shall also be pulverized to the depth shown on the plans and mixed with the asphaltic material.

Immediately after pulverizing, the material shall be placed as shown on the plans. The laydown shall be accomplished using a paver or a grader or a combination of a paver and grader.

The relaid material shall be immediately compacted in the following sequence: first with either a rubber-tired roller or vibratory pads foot roller, and second with a vibratory steel roller. Water shall be added prior to and during compaction as required. Each layer shall be compacted to the extent required for Standard Compaction in Section 304.5 of the Standard Specifications. The compaction equipment shall be as follows:

> For a compacted depth of pulverized material, up to 150 mm, compaction equipment shall be in accordance with Section 304.4.4 of the Standard Specifications.
>
> For a compacted depth of pulverized material, greater than 150 mm and up to 200 mm, a minimum 22.68 megagram rubber-tired roller with 620 kPa tire pressure or 11335 kg pads foot vibratory roller, and a minimum 7.25 megagram vibratory steel roller shall be used.
>
> For compacted depths greater than 200 mm, split lift compaction according to the above described methods will be required.

At the completion of each working day, the ends of the pulverize and relay asphaltic pavement and base course shall be as adjacent as practical for both traffic lanes.

C. Method of Measurement. Pulverize and Relay Asphaltic Pavement will be measured by the square meter of relaid material according to the finished typical section width and details shown on the plans.

D. Basis of Payment. Pulverize and Relay Asphaltic Pavement, as measured above, will be paid at the contract unit price per square meter, which price shall be full compensation for pulverizing, windrowing, relaying, adding water, compaction, removing and disposing of excess material, and all labor, tools, equipment, and incidentals necessary to complete the work in accordance with the contract.
(022096)